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# Ultrasound of distal brachialis tendon attachment: normal and abnormal findings

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**Objective:** To demonstrate normal and abnormal findings of distal brachialis tendon attachment in cadavers, normal volunteers and patients by means of ultrasound.

**Methods:** 3 cadaveric specimens, 30 normal volunteers and 125 patients were evaluated by means of ultrasound. Correlative MRI was obtained in volunteers.

**Results:** In all cases, ultrasound demonstrated the distal brachialis tendon shaped by two distinct tendons belonging to the deep head and superficial head of the brachialis muscle. Correlative MRI demonstrated that the brachialis is composed of two distinct tendons in 83% of volunteers (25/30). In the patient group, four avulsions with bony detachment involving the deep head, one delayed onset muscular soreness and three tendinous

detachments with no bony avulsion involving one or two tendons were identified. The four patients with bony avulsion were immediately referred to the orthopaedic surgeon for a pre-surgical evaluation. Patients without bony avulsion were not referred to the surgeon.

**Conclusion:** Detailed anatomy of the distal tendon is discernible in 100% of cases with ultrasound. There are two distinct tendons, and ultrasound can differentiate isolated lesions. In patients with distal brachialis tendon lesions, ultrasound may modify the clinical management of the patient.

**Advances in knowledge:** Detailed anatomy of the distal brachialis tendon is discernible with ultrasound and there are two distinct tendons.

The distal insertion of the brachialis on the ulnar tuberosity has been described as purely muscular, tendinous or mixed. The brachialis muscle insertion is described as a single broad tendon or as having two heads, one with a tendinous and the other with an aponeurotic attachment [1,2]. Recent studies on cadavers found that two heads compose the distal attachment of the brachialis, a superficial head and a deep head [1,3]. The larger, superficial head originates from the anterolateral aspect of the middle third of the humerus and the lateral intermuscular septum, whereas the smaller, deep head originates from the distal third of the anterior aspect of the humerus and the medial intermuscular septum. Moreover, it has been stated that the brachialis muscle has a double innervation: the main innervation of the brachialis muscle by the musculocutaneous nerve and additional branches from the radial nerve [4–7]. To the best of our knowledge, there are no reports assessing whether ultrasound and MRI are able to demonstrate the two heads of distal brachialis attachment *in vivo*. Therefore, the purpose of the present study was to assess whether ultrasound and MRI are able to differentiate the two components of the brachialis muscle distal attachment in cadavers, normal volunteers and patients with tears of the brachialis tendon involving one of the two parts of the distal tendon.

## METHODS AND MATERIALS

The Institutional Review Board of the University of Barcelona, Barcelona, Spain, approved this study, and all the volunteers and patients gave written informed consent.

### Anatomical correlation

The anatomical correlation part of this project was approved by the Anatomic Donations Department in

Barcelona. The anatomy of the distal brachialis bifurcation was at first evaluated on three cadaveric arms (males: 44, 65 and 69 years old) dissected by an anatomist with 20 years of experience in dissection from the shoulder to the forearm. The specimens were deep frozen at  $-40^{\circ}\text{C}$ . Plain films were obtained to exclude concomitant osseous pathology at the level of the elbow. No evidence of previous surgery around the elbow was observed. The specimens were thawed to demonstrate the distal insertion of the brachialis muscle. Visual inspection was performed by a musculoskeletal radiologist who had more than 5 years of experience in musculoskeletal imaging and by a rehabilitation specialist who had more than 5 years of experience in dissection. This procedure had been performed already to isolate the distal biceps tendon [8].

### Ultrasound and MRI examination

Ultrasound imaging of the distal brachialis tendon was performed in 30 consecutive normal volunteers (15 males and 15 females; age range: 22–45 years) with commercially available equipment (iU22; Philips, Eindhoven, Netherlands) and broadband (frequency band: 5–17 MHz and 7–12 MHz) small parts linear array transducers. Examinations were performed by 2 radiologists who had 20 years and more than 5 years of experience in musculoskeletal imaging. The volunteers sat in front of the examiner, with the elbow resting on the examination table. Ultrasound examination was performed on axial planes, moving the transducer up and down and on longitudinal planes. The distal brachialis tendon was evaluated from its origin to the insertion onto the ulnar tuberosity. Once the tendon was visually detected on the base of the typical fibrillar echotexture, it was kept in the centre of the field of view. Anisotropy and

Figure 1. (a) Cadaveric axial view of brachialis insertion. (b) Cadaveric view of the superficial head insertion. (c) Cadaveric view of the deep head insertion. TSH, tendon of the superficial head; DH, deep head; U, ulna; R, radius.

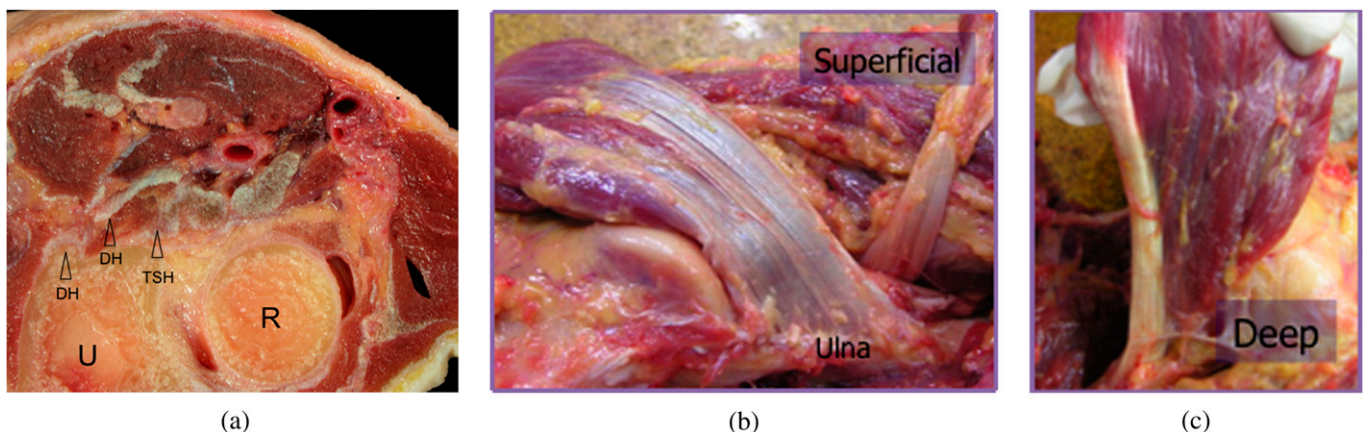
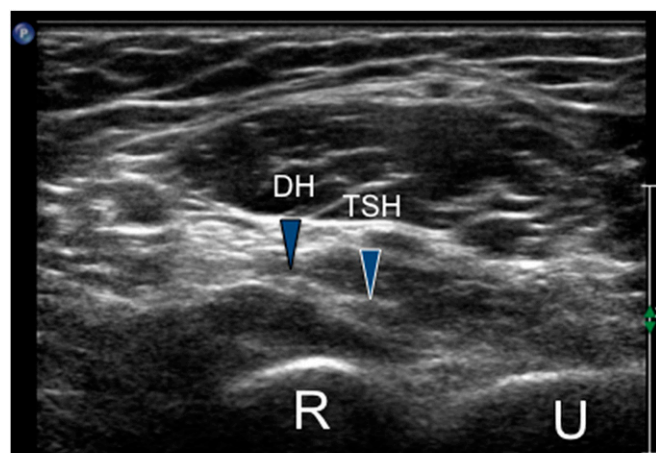
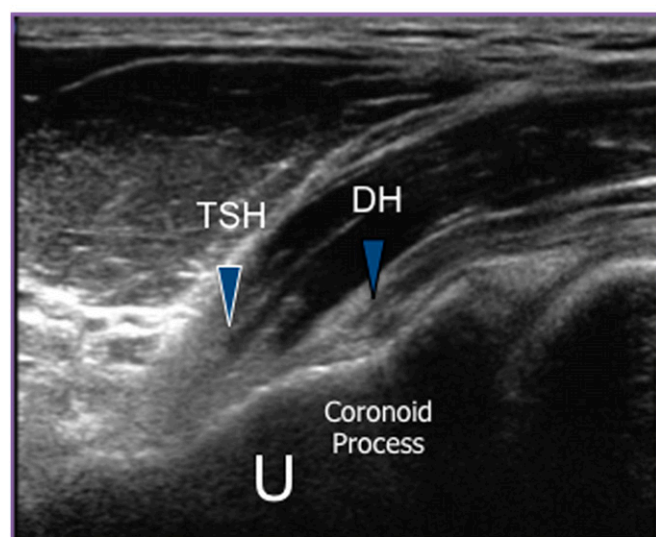


Figure 2. (a) Ultrasound axial view of brachialis insertion. (b) Ultrasound longitudinal view of brachialis insertion. TSH, tendon of the superficial head; DH, deep head; U, ulna; R, radius.



(a)



(b)

pronosupination movements were used to identify the two separate tendinous components belonging to the superficial head and the deep head of the brachialis. Anisotropy represents a change in echogenicity of the

tendon owing to changes in inclination of the ultrasound beam: when the probe is not perpendicular to the tendon, it tends to become hypoechoic and more difficult to assess owing to loss of contrast resolution. To take advantage of anisotropy, the steering options were switched off. Pronosupination movements were performed to assess whether the two tendons, the superficial head and the deep head, move together or separately. This manoeuvre was also performed to differentiate the two components of the distal biceps brachii tendon [8]. Correlative MRI was obtained in normal volunteers and this was obtained using 1.5 Tesla equipment (MAGNETOM® Avanto Syngo MR 2004V; Siemens AG, Erlangen, Germany; gradients  $25 \text{ mT m}^{-1}$ , slew rate  $800 \text{ Tm}^{-1} \text{ s}^{-1}$ , rise time  $400 \text{ ms}^{-1}$ ) using a flexible surface coil and the following protocol:  $T_1$  weighted spin echo (TE, 15.0 ms; TR, 500–650 ms; matrix,  $384 \times 384$ ; slice thickness, 3.5 mm; field of view,  $15.0 \times 15.0 \text{ cm}$ ; number of excitations, 3), and fat-suppressed  $T_2$  weighted turbo spin echo [8]. All acquisitions were obtained on axial and longitudinal planes. The use of MR as a reference standard could represent a limitation because it has not been proven yet that MR is able to differentiate the two tendinous components of the distal brachialis attachment. However, MRI was considered an acceptable compromise, and it was able to differentiate the two tendinous components of the distal biceps tendon [8]. 125 patients were referred by the Orthopaedic Department of the University of Genova, Genoa, Italy, to the Radiology Department between January 2006 and May 2011 for an ultrasound elbow evaluation. The ultrasound protocol used for the patients was the same as that employed for the volunteers. The database of elbow ultrasound examinations revealed the patients with brachialis abnormalities.

## RESULTS

At the time of dissection, visual inspection of the distal brachialis muscle attachment revealed that the superficial

Figure 3. MRI axial view of brachialis insertion, from proximal to distal, in a 35-year-old volunteer. The more proximal image is on the left. TSH, tendon of the superficial head; DH, deep head.

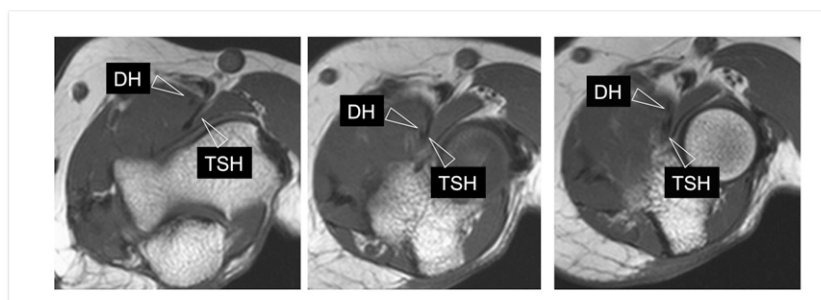
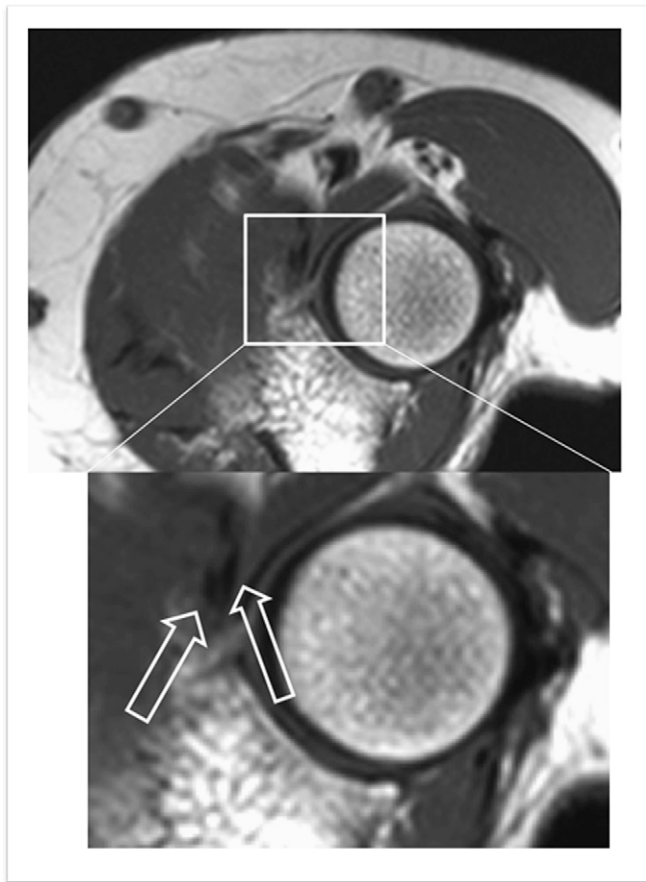




Figure 4. Magnification of the distal insertion of the brachialis tendon. The two tendinous components of the brachialis muscle are represented by void arrows.



head and the deep head of the brachialis could be differentiated. The attachment of the superficial head onto the ulnar tuberosity was more distal than that of the deep head. The deep head inserted more broadly to the ulnar tuberosity and coronoid process. The deep head insertion was medial to the insertion of the tendon of the superficial head (Figure 1). The cross-sectional area of these two separate entities was different on visual inspection: at the

level of insertion, the superficial head appeared thicker and rounded, but the deep head more elongated and aponeurotic [ $8.3 \pm 3.1 \text{ mm}^2$  for the deep head (DH) and  $4.8 \pm 2.2 \text{ mm}^2$  for the tendon of the superficial head].

Ultrasound of the normal volunteers demonstrated similar findings. The two distal tendons of the brachialis were identified on axial planes as fibrillar structures, one adjacent to the other at the myotendinous junction; then, more distally, they changed orientation with the superficial head located in a superficial position and the deep head in a deeper position. On axial planes, the tendon of the DH was located in a more medial position than that of the superficial head, and it was slightly smaller (Figure 2). This difference in cross-sectional area was more evident proximally, possibly because of the aponeurotic nature of the deep head, which makes it difficult to evaluate and measure with ultrasound and MRI. MRI confirmed the differences in shape of the two tendons (Figures 3 and 4). Ultrasound probe shifting was essential to take advantage of the anisotropy artefact. This artefact was useful for identifying the two components of the distal brachialis. Pronosupination movements of the arm determined a change in the position of the tendons, which made it clearer that these two components were distinct. On ultrasound imaging, differentiation between the two separate tendinous components was possible on short- and long-axis planes. Correlative MRI demonstrated that the brachialis is composed of two distinct tendons in 83% of volunteers (25/30). MRI was evaluated by two musculoskeletal radiologists who had more than 5 and 20 years of experience, using the commercially available equipment of the Radiology Department. The two distinct tendons were seen equally well on  $T_1$  weighted spin echo and fat-suppressed  $T_2$  weighted turbo spin

Figure 5. MRI axial view of brachialis tendons in a 42-year-old volunteer. Note that the visualisation of the tendons (void arrows) is possible on  $T_1$  weighted sequences ( $T_1w$ ) and on  $T_2$  weighted sequences with fat saturation ( $T_2w\text{-fs}$ ).

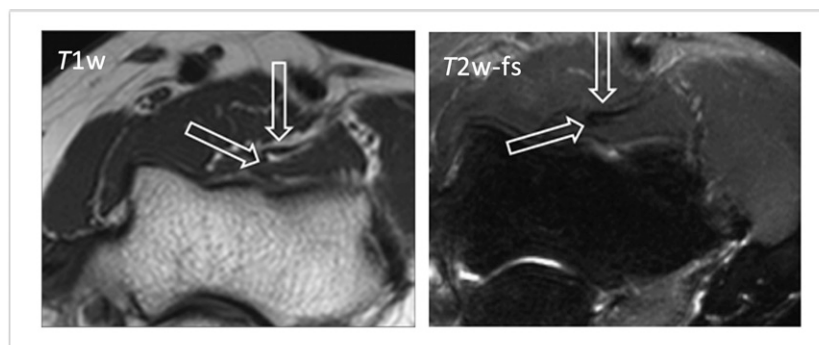
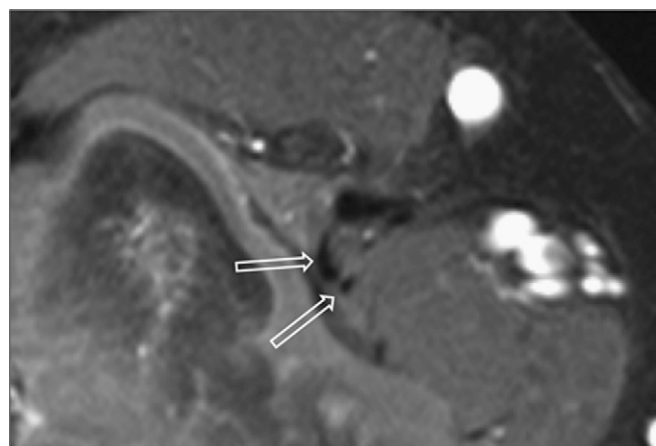


Figure 6. MRI axial view of brachialis tendons in a 45-year-old volunteer. Note the visualisation of the brachialis muscle tendons (void arrows) on this  $T_2$  weighted sequences with fat saturation.



echo sequences on axial planes (Figures 5–7). Longitudinal MRI planes failed to differentiate the two components. Among the patients admitted to our department for evaluation of the elbow, we identified four avulsions (confirmed with plain films in a subacute clinical presentation) with detachment of a fleck of bone from the coronoid process involving the deep head (Figure 8), one delayed onset muscular soreness (presumably a low-grade muscle injury after a body-building session) in a 32-year-old male patient (Figure 9)

and three lesions (tendinopathy with loss of the normal fibrillar structure of the tendon) with no bony avulsion involving one or two tendons (Figure 10). The four patients with bony avulsion were immediately referred to the orthopaedic surgeon for a pre-surgical evaluation. Patients without bony avulsion were not referred to the surgeon. Apart from the patient with delayed onset muscular soreness, the others had a history of a single traumatic event that determined a sudden forced hyperextension of the muscle against resistance. In these patients, longitudinal ultrasound planes were essential for identifying the two separate tendons belonging to the distal brachialis tendon as a whole. On ultrasound axial planes, identification of the head involved was less reliable.

## DISCUSSION

Knowledge of a more detailed anatomy of the distal brachialis tendon may enhance the accuracy of ultrasound and MRI. This has a clinical value for patient management in deciding between a surgical or a conservative therapy. Moreover, this observation may have implications for development of new techniques for brachialis tendon repair and reconstruction. The anatomic appearance of the distal attachment of the brachialis muscle has not been well characterised in a majority of anatomical textbooks [5,6]. In this study, we tried to

Figure 7. MRI axial view of brachialis tendons in a 55-year-old volunteer. Note the visualisation of the tendons (void arrows) on  $T_1$  weighted sequences ( $T_1w$ ) and on  $T_2$  weighted sequences with fat saturation ( $T_2w$ -fs) at proximal and distal levels.

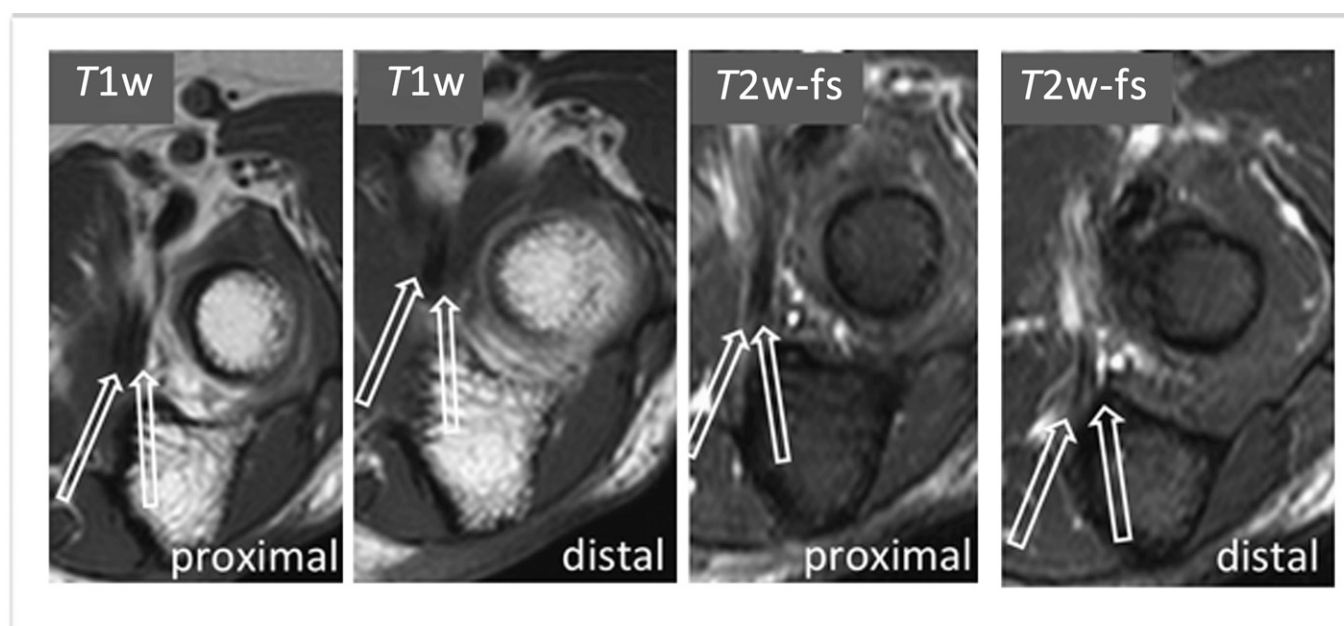
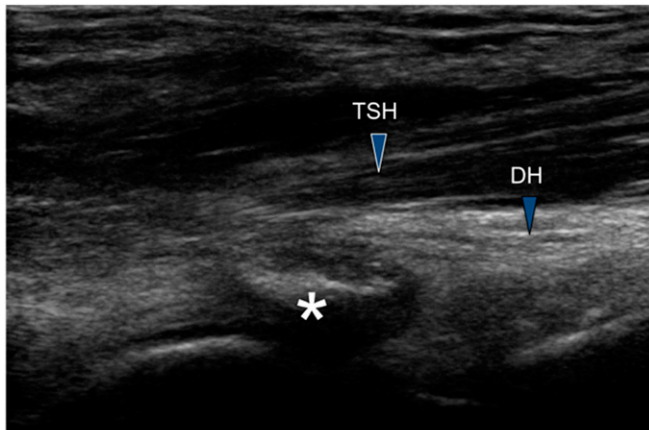
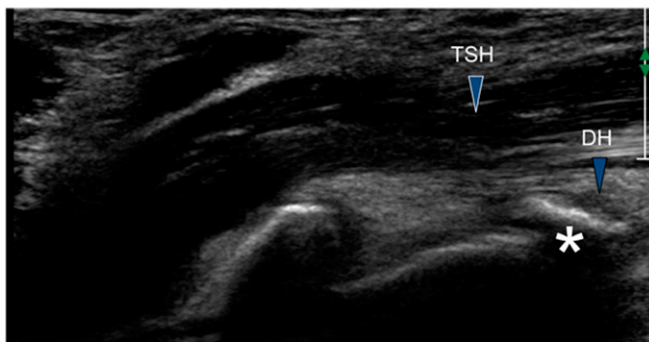


Figure 8. (a) Longitudinal ultrasound image in a 54-year-old patient with bony detachment (asterisk) at the coronoid insertion of the deep head of the brachialis. (b) Longitudinal ultrasound image in a 23-year-old patient with bony detachment (asterisk) at the coronoid insertion of the deep head of the brachialis. TSH, tendon of the superficial head; DH, deep head.



(a)



(b)

assess if ultrasound and MRI are able to identify the two components of the distal brachialis muscle in cadavers, normal volunteers and patients. In the first part of the study, both techniques were able to identify the two components of the brachialis muscle. On ultrasound, both axial and longitudinal planes were adequate to correctly identify the deep head and the superficial head of the brachialis muscle. On the other hand, MRI identified the two components of the brachialis muscle insertion only on axial planes, both on  $T_1$  and  $T_2$  weighted sequences. Longitudinal MRI planes failed to differentiate the two components of the brachialis muscle. A possible explanation may be that the muscle has an oblique course, and it is difficult to have the whole insertion in a single slice. A possible solution could be represented by the use of three-dimensional sequences, but our clinical protocol did not include these kinds of sequences for the elbow. In the group of patients, the

Figure 9. (a) Longitudinal ultrasound image in a 30-year-old patient with delayed onset muscular soreness. The muscle is markedly swollen and hyperechoic in comparison with the contralateral side (b). SH, superficial head; DH, deep head.



(a)



(b)

presence of oedema and effusion made ultrasound longitudinal planes more suitable to differentiate the two heads of the brachialis muscle. Both ultrasound and MRI were able to identify correctly the lesions in the group of patients; however, small bony avulsions of the coronoid process were more easily visible with ultrasound. From the biomechanical point of view, it is not surprising that detached bony fragments were related to the deep head. Indeed, the deep head has a more anterior insertion on the coronoid process, leading to a more heavy load on the bony insertion.

Knowledge of a more detailed anatomy of the distal brachialis tendon may enhance accuracy of ultrasound and MRI. In this study, it seems that ultrasound may



Figure 10. Longitudinal ultrasound image in a 54-year-old patient with detachment at the coronoid insertion of the deep head and the superficial head of the brachialis with no bony avulsion. SH, superficial head; DH, deep head.



be better than MRI for differentiating between the two tendons. Indeed ultrasound can differentiate between the 2 tendons in 100% of cases and MRI in 83% of cases, probably owing to technical limitations. Indeed, it is important to remember that the accuracy of MRI depends on the machine, the coil and the protocol.

The limitations of our study included the relatively small number of cadavers, volunteers and patients. However, correlation among dissection, ultrasound and MRI findings was generally achieved. We also have to acknowledge that MRI and surgical correlation was not obtained in every patient. However, there is sufficient medical literature to consider ultrasound reliable in the diagnosis of tendon disorders [9]. Distal brachialis lesions are extremely rare, and we are not aware of any report describing the capabilities of ultrasound to identify isolated lesions of one or both components. Only six cases involving traumatic rupture of the brachialis muscle were described in the past 20 years, and only one with ultrasound [10]. However, in this case, ultrasound failed to assess if one or both components of the brachialis muscle were involved.

In conclusion, our study demonstrates that ultrasound is able to differentiate between the two distinct components of the distal brachialis tendon. Moreover, ultrasound has the potential to distinguish isolated lesions of one of the two components. These findings may modify the clinical management of the patient.

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